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INFORMATION REPORT INFORMATION REPORT

# CENTRAL INTELLIGENCE AGENCY



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|---|---|---|---|
| COUNTRY | USSR | REPORT | [redacted] |
| SUBJECT | Additional Data on the Command Control System of the Soviet RSNA-75M (FAN SONG) Radar | DATE DISTR. | 6 August 1964 |
| | | NO. PAGES | 18 |
| | | REFERENCES | [redacted] |
| DATE OF INFO. | [redacted] | | |
| PLACE & DATE ACQ. | [redacted] | | |

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Distribution of Attachment:

[redacted]

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OSI - Retention

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INFORMATION REPORT INFORMATION

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August 1964

COUNTRY : USSR

SUBJECT : SA-2 Missile System

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2. Except for the designation of the radar itself, which has been transliterated, the Cyrillic designation of the units has been retained.

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1. Signal $h\Delta\epsilon$ is generated linearly to the value $h\Delta\epsilon = 1200$m, ($\pm$ 102V). After this limiting may take place. From converter output signal $h\Delta\epsilon$ is applied to the summary amplifier $h\epsilon$ to which the range angle correction signal hkg is also supplied and finally, in the case of lead operating mode lead signal $h\lambda\epsilon$ is fed. The error signal $h\epsilon$ in the form of a DC voltage is shaped at the summary amplifier output. In the lead operating mode $h\epsilon = h\Delta\epsilon + hkg - h\lambda\epsilon$. In the three-point operating mode $h\epsilon = h\Delta\epsilon + hkg$. The $h\epsilon$ error signal scale at the summary amplifier output is 0.0855 volt per meter. The error signal is generated linearly up to the value $h\epsilon = \pm$ 800 meters ($\pm$68 V). The $h\epsilon$ error signal from the summary amplifier output is supplied to the $h\epsilon$ limiter and to the $\lambda_\epsilon$ operational amplifier. From the limiter output, limited error signal $\overline{h}_\epsilon$ is also fed to the operational amplifier. The error signal is limited at a level of $\pm$75 m ($\pm$15 V) according to the formula

$$\overline{h}_\epsilon = h_\epsilon \text{ when } |h_\epsilon| < h_o = 175 \text{ m}$$
$$\overline{h}_\epsilon = h_o + \frac{1}{6}(h_\epsilon - h_o) \quad \text{when } |h_\epsilon| > h_o$$

2. Signal $h\lambda\epsilon$ is generated linearly way up to the value $h\lambda\epsilon = \pm1200$ m ($\pm$0.275 ma). In the lead operating mode $h\lambda\epsilon$ is delivered to the summing amplifier which converts the current proportional to $h\lambda\epsilon$ into a voltage and at the same time summarizes the error signal components. The signal scale at the summing amplifier output is similar to that of other components of the error signal at the summing amplifier output and is equal to 0.855 v/m. The time mechanism shown on the functional diagram performs the following operations: it generates voltage R(t) and R'(t), multiplier signals $\dot{\epsilon}$ and $\beta$ cos $\epsilon$ by time function X(t), and generates 26-volt "single" and "end of operation" commands. The end of operation command is not shown on the diagram. The single command is given approximately 22.6 seconds after the launch of the missile. The end of operation command is given after the mechanism has reached its final position — approximately 55 seconds after the missile launch. This command is fed to guidance operator unit И62М.

3. In addition to the input signals described in the functional diagram (pulses $\epsilon_o, \epsilon_u, \epsilon_p, \beta_o, \beta_u, \beta_p$ and voltages $\dot{\epsilon}$, $\dot{\beta}$ cos $\epsilon$, $\dot{\beta}$ sin $\epsilon$ ), the following switching commands, controlling through relays the K80a cabinet operating conditions are fed to cabinet K80a as $\pm$26-volt signals: " У —T/P" (three points). Single command selection (time mechanism-$\Delta\lambda$) (single command selection) "$D_\epsilon$ correction off" (cutting off the range angle correction signal in $\epsilon$ plane channel). "$D_\beta$ correction off" (cutting off range angle correction signal in $\beta$ plane channel) "start" "radio control switched on" "zero check" "check permission."[1]

4. The start command is fed to cabinet K80a through the И62М guidance operator unit. The command radio control switched on (sic) is fed to the K80a cabinet from K70БA a cabinet of the corresponding channel after the missile has been locked on three coordinates. The other commands are fed from guidance operator unit И62М ( УA). " У—T/R" (three points) command is applied in two cases: when there is active jamming and target range coordinate data are not fed to the K80a cabinet and in the case of small target angular speeds when it is not expedient to

introduce the lead. In this case $h\lambda\epsilon$ and $h\lambda\beta$ lead signals are not delivered to the outputs of the respective summing amplifiers and guidance is carried out by the target bracketing method (three points). At the same time the dynamic error compensation signal value ($h\partial\epsilon$ and $h\partial\beta$ ) is switched over. The command "TM single command selection $\Delta\lambda$ " is applied when there is jamming and target range coordinate data are not fed to cabinet K80a. In this case the single command is fed from the time mechanism to the command radio transmitter. When command "single command selection" is not applied to single command, (sic - this discontinuity appears in the original) is fed from the single command circuit to the command radio transmitter. The $D_\epsilon$ or $D_\beta$ correction cut-off is fed to the K80a cabinet under jamming conditions when the station receives through the $\epsilon(\beta)$ channe the jammer signal rather than the echo signal reflected from the target. When applying the $D_\epsilon$ or $D_\beta$ correction cut-off command the range angle correction signal is cut off in the channel of the corresponding plane.

5. After the start command is fed to the K80a cabinet the time mechanism operation begins. When the command start is cut off the time mechanism returns to the initial position. The start command is cut off after the time mechanism reaches its final position, that is, when the end of operation command is fed from the K80a cabinet to the И62m guidance operator unit. Thus the time mechanism of the station returns to the initial position automatically. When applying the radio control switching command to the K80a cabinet the $K_1$ and $K_2$ commands are fed to the command radio transmitter and the rotation introducing device begins to operate. Before the application of this command the K80a cabinet outputs are grounded to the chassis for $K_1$ and $K_2$. After the zero check command is fed to the K80a cabinet the switching is performed for checking the zero readings of commands $K_1$ and $K_2$ during joint operation of the K80a cabinet and the station coördinate units with the command radio transmitter equipment.

6. Applying the check permission command enables transition of cabinet K80a to the monitoring operating condition. The $D_\epsilon$ and $D_\beta$ correction cut-off commands, zero check and check permission are fed at the same time to all three K80a cabinets in van AA. The same applies to pulses $\epsilon_o$, $\epsilon_u$, $\beta_o$, $\beta_u$, $\lambda_o$ command generating system and signals $\epsilon$, $\beta \cos \epsilon$ and $\beta \sin \epsilon$. The other commands and pulses are fed to each K80a cabinet separately.

7. The breakdown by units of the assemblies shown in the functional diagram is as follow:

8. Unit K81 (error signal generating unit) is designed to generate angular error signals $h\Delta\epsilon = \Delta\epsilon R(t)$ and $h\Delta\beta = \Delta\beta R(t)$ proportional to the missile deviation from the target sighting line in the elevation and azimuth. The unit contains $h\Delta\epsilon$ and $h\Delta\beta$ converters. In addition the unit contains auxiliary equipment necessary for tuning and checking the K81 unit as well as the rest of the cabinet. Among these elements are a simulator and a vacuum-tube voltmeter.

9. Unit K82 is designed for shaping $hr\epsilon$ and $hr\beta$ lead signals and $h\epsilon$ and $h\beta$ error signals. The unit includes the following assemblies: $r_p$ and $r_u$ blocking oscillators, $\Delta r$ trigger, $2\Delta r$ shaping circuit, dividing and multiplying device, $hr\epsilon$ and $hr\beta$ converters, $h\epsilon$ and $h\beta$ summing amplifiers, simulator.

10. Unit K83 is designed for shaping control signals $\lambda_\epsilon$ and $\lambda_\beta$ of the station coordinates and for converting them into control commands $K_1$ and $K_2$ of the missile coordinates, adjusting for the rotation angle.

11. The K83 unit contains $h\epsilon$ and $h\beta$ limiters, $\lambda_\epsilon$ and $\lambda_\beta$ operational amplifiers, $\lambda_\epsilon$ and $\lambda_\beta$ limiters, $\lambda_\beta$ inverter, $\gamma$ integrator, rotation introducing device for generating voltage R(t) and R'(t), dynamic error compensation signals $h\partial\epsilon$ and $h\partial\beta$ , range correction angle signal hkg and time commands "single command" and "end of operation."

12. Unit K84 comprises the time mechanism, dynamic error compensation signal shaping circuit, single command circuit, $h\epsilon$ and $h\beta$ memory circuit.

13. Unit K180 contains three stabilized amplifiers for +250, -200 and -500 volts. The latter voltage stabilizer consists of a -200-volt and a-300-volt stabilizers connected in series operating with common stabilizer of pedestal voltage (СГ1П ).

The Radio Command Transmitter

14. The radio command transmitter (РПК) is the ground unit of the missile radio control equipment. The receiving unit ( ФР-15АК) is mounted on board the missile. Commands $K_1$ and $K_2$ controlling the missile movement in two mutually perpendicular planes and one command ($K_3$ ) for arming the proximity fuse are transmitted via the radio channel. In addition board responder triggering pulses (pulse $r_o$ of РПК) are transmitted via the radio channel.

15. Radio control permits three missiles to be controlled simultaneously. For this purpose three independent groups of $K_1$ , $K_2$ , and $K_3$ commands are transmitted from РПК. Commands $K_1$ and $K_2$ are fed to command radio transmitter from the command generating system of all three channels and are represented by slowly changing dc voltages. The command voltages may vary approximately from -100 to +100 volts. The command transmission band from РПК is within -50 to +50 volts. Voltages beyond these values are limited. Command $K_3$ is also fed to the РПК input from the command generating system as a +26-volt signal switched on during application of command $K_3$ .

16. The $r_o$ pulses transmitted through the РПК have the same 2500 pps ± 10% repetition frequency as the main pulses of the target sighting channel but are ahead of them by the delay provided in the missile board equipment. They are fed to the РПК input from the station pedestal voltage system. The transmitted commands are converted into high frequency pulses by the РПК.

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17. When transmitting each command a group of pulses with a repetition frequency of $4F_0$ is introduced into the signal. When the command voltage is applied to the P П K input and has width of approximately 0.2 sec. $\mathcal{R}_0$ pulses are formed in the P П K in width only and delayed.

18. The sum of all the pulses — nine command and the $\mathcal{R}_0$ pulses of the P П K — amplitude modulate the high frequency oscillator operating in the pulse mode. To provide separation of the different pulses in the board equipment the $\mathcal{R}_0$ pulses of the P П K are half the width of those of the above pulse group. Permitting their separation in the board equipment by selection in width. Locked mutual synchronization is used to avoid interference of different pulses with each other and with the $\mathcal{R}_0$ pulses when command values are varied in value. A number of discrete positions locked in phase with the $\mathcal{R}_0$ pulses is given for each command pulse. For this purpose the pulse voltages in the P П K are generated from 22.5 kc pulses applied from station synchronization unit (И 91). Due to discrete displacement of the command pulses the continuous scale of values transmitted through the command radio line is replaced by the discrete scale. About ± 25 levels corresponds to command values of ±50 v.

19. The P П K equipment comprises: (1) coder (2) transmitter (3) monitoring equipment (4) power supply. The coder transforms the command voltages fed to the command transmitter input into pulse voltages and in addition shapes the P П K $\mathcal{R}_0$ pulses. The transmitter amplifies these pulses and then converts them into powerful high frequency pulses applied through the feeder to the antenna. The monitoring equipment provides a check on the condition of the whole station and facilitates tuning of the equipment and trouble shooting. The power supply sources provides the P П K equipment with the necessary electric power. Diagram No. 23 shows the coder, transmitter, monitoring equipment and their interconnection.

20. The coder of the P П K includes: synchronizer (unit Л71), pedestal voltage unit (Л75) command converter (Л72), three units for three channels, rating unit (Л73). The transmitting device consists of modulator unit (Л22), generator unit (Л21), T/R antenna switch, power and envelope (sic) indicator (Л24), automatic frequency control (Л23) and dummy antenna (Л25). Units Л71 and Л75 generate pulse voltages for synchronizing all the elements of the coder. Frequency pulses of 22.5kc ($F_1$) applied to unit Л71 from the station synchronizer unit И91 serve as pedestal voltages. In unit Л71 dividing repetition frequency of these pulses by eight gives a number of pulse sequences used for time correction of command $K_1$ and $K_2$ pulses in units Л72 for their discrete time positions. These sequences exclude interference of different command pulses. Two of the sequences received are employed in unit Л75 to shape coincidence pulses and single command pulses.

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21. The РПК $Д_0$ pulses fed to РПК input from the synchronizer are shaped in width in unit Л71 and then applied to the modulator input (Л22). During combat operation, unit Л71 operates with external synchronizing by pulses fed from unit И91, but in monitoring operation the unit may operate with internal synchronization. In this case both sequence pulses $F_1$ and $Д_0$ are generated by an auxiliary unit of Л71. This operating method is used during autonomous test of the РПК equipment.

22. Further division of synchronizing pulse repetition frequency takes place in unit Л75. The frequency is first reduced to the pulse repetition frequency of single commands $F_3 = \frac{F_1}{128}$ and then to frequency $F_0 = \frac{F_1}{512}$. The unit represents three sequence pulses and pulse T. In addition this unit shapes voltage $F_0$ necessary for operation of $K_1$ and $K_2$ command converters.

23. Transformation of command voltages into pulse voltages is performed by three Л72 units. Each of them converts all the commands ($K_1$, $K_2$, $K_3$ ) of one channel. All three units are alike. Respective channel commands and command correction pulses are fed to the input of these units. Each Л72 unit contains three converters (   number of commands). Two sequence pulse are obtained at the output of each Л72 unit. When transmitting command $K_3$ one more pulse group appears at the unit output. In unit Л73 these pulses are shaped in width and fed to one of the ( Л22) modulator inputs. The modulator amplifies video pulses to a level of the order of 13 kw and applies them to the hf generator.

24. The modulator has two pulse amplifying channels: a pulse channel and the $Д_0$ pulse channel. Each channel is a three-stage pulse amplifier with transformer coupling between stages. ГМИ90 tubes operate at the input (sic) of each channel. The pulse transformer is a common plate load. From the secondary winding of the transformer the pulses are presented to the generator tube plate (unit Л21). The RF oscillator employs a circuit with the common grid using a type ГИ-14Б metal-ceramic tube. Grid plate and grid cathode circuits employ coaxial lines and are located on one side from the grid plane (sic). The oscillator is coupled to the load by means of coupling probe which has a galvanic (sic) contact with the oscillator grid cylinder.

25. High-frequency pulses are fed from the generator output plug connector to the antenna switch (unit Л24) providing for application of the pulse either to the antenna or to the dummy antenna (Л25). The oscillator is connected to the antenna only during the launch of a missile. During that time signal "РПК antenna on" is fed to the van input. The remainder of the time the oscillator feeds into the dummy antenna.

26. Frequency stability is guaranteed by automatic frequency control. For this purpose a capacitive probe is inserted to the generator grid-plate circuit near the voltage loop. Depth of its sinking is measured by means of a small motor connected with the probe by the reducer. (sic). A mistuning signal proportional to the frequency deviation from the rated value is generated in unit Л23. It controls the motor to effect correction. For this purpose frequency of oscillation in the unit is checked against a harmonic of the crystal oscillator.

27. Output is fed to a parabolic antenna with a spiral radiator producing circular polarization. The antenna beam width at half power point throughout the frequency band lies within the limits of 10° -- 14.5°. The side lobes power level is not more than 5%. This value of beam width make it possible to control the missile in any point of the station view sector. Circular polarization provides reliable communication with the missile at any angle of revolution of the latter. The РПК antenna is firmly fixed to the sighting azimuth antenna ( ПА-11). The maximum of the antenna radiation pattern coincides with the view sector bisector. To provide pattern rotation in azimuth plane use is made of the rotating coupling in the feeder. Tilting in vertical plane is permitted by the flexibility of the feeder cable.

<u>The Impact Point Range Generating Unit</u>

28. The purpose of unit И87 is to determine the slant range to the impact point according to the continuous data of the target's position in space at any given moment. Unit И87 is an electronic computer that solves the impact problem on the bases of hypotheses on uniform rectilinear motion of a target at a constant altitude. The slant range signal generated by the unit is supplied to the guidance indicator of unit И32 in the form of a data voltage pulse. The slant range to the impact point is marked with a horizontal marker on the screen of the $\epsilon$ or $\beta$ guidance indicator. If the unit И87 horizontal mark is within range of the radar, the guidance operator may fire the missile.

29. Fig. 24 shows the space in which an air target moves and the location of the guidance radar station. Assuming a constant velocity rectilinear motion of the target, on a plane drawn through the target motion line and the station location point

$$OB = OC + CB = OA \cos\phi + AB \cos\gamma \quad (1)$$

Where OB = Running slant range to the target $r_{ц}$

OA = Slant range to the impact point $r_{б}$

AB = Distance the target will cover from the given position to the impact point

It is evident that the target will cover distance AB for the time equal to that of the missile flight from the starting point up to the point of impact. Thus if

$$AB = V_ц t_п = V_ц \frac{r_б}{V_p} \qquad \text{Equation (1)}$$

Becomes

$$r_ц = r_б \cos\phi + V_ц \frac{r_б}{V_p} \cos\gamma_ц$$

$$r_б = \frac{r_ц V_p}{V_ц \cos\gamma_ц + V_p \cos\phi} \qquad (2)$$

Product $V_ц \cos\gamma_ц$ is the variation of slant range $r_ц$ with time. That is

$$V_ц \cos\gamma_ц = r_ц \qquad (3)$$

Thus the final formula for determining the range becomes[2]

$$r_б = \frac{r_ц V_p}{\dot{r}_ц V_p} \qquad (4)$$

30. Determining the range $r_б$ according to this formula requires the following information: target range $r_ц$ rate of range variation ( $\dot{r}_ц$ ), and missile average speed ($V_p$ ). Information on range and its rate of change is obtained from the coordinate units as the time lapse between pulses $r_o$ and $r_ц$.

31. The missile average speed value is generated within the unit itself using the mutual dependence between the missile flight range and speed $V_p$ approximated by

$$V_p = V_{po} + k_1 r_б \qquad (5)$$

Where

$V_{po}$ = 450 meters per second

$k_1$ = 5.5$\mu$seconds per kilometer

32. When there is jamming, information on the target range is not fed from the coordinate units. Under such conditions range value is generated in unit И87 according to equation

$$r_ц = \frac{H}{\sin\epsilon_ц} \qquad (6)$$

where $\epsilon_ц$ is the elevation obtained from unit И65М and target altitude H from the target external designation means (sic).

33. When the target is at an angle of less than 5.5° determining the target range becomes more complicated since the antenna is in a fixed position. The target is tracked in angle inside the scan sector by displacing the tracking gates. Therefore in addition to a high altitude operating mode provision is made for a low altitude operating mode. In that case the range is determined as follows:

$$r_ц = \frac{H_{\Gamma}}{\epsilon_{цH} - k} \qquad (7)$$

where H is the altitude set with a potentiometer in the elevation angle inside scanning sector

k = 0.0344 radians.

Thus the unit may be used to operate in the "lead" and "three point" operating modes at high target altitudes and in the "three point" mode at low altitudes.

34. Fig. 26 is a functional diagram of unit И87 including the following main assemblies:

— Converter for transforming the interval between pulses $Д_0$ and $Д_4$ into a DC voltage. It consists of input $Д_0$ and $Д_4$ blocking oscillators, $Д_4$ trigger, $Д_4$ inverter and converter proper with a filter in the plate circuit, $\hat{Д}_4$ differentiating amplifier.

— $Д_4 V_p$ — an elementary multiplying circuit employing an electronic key with a filter.

— $Д_6$ multiplier — a closed tracking system consisting of a DC amplifier, comparator, saw-tooth oscillator with pulse triggering delay circuit and a feed key (sic). The square-wave voltage of the comparator has a mark space ratio proportional to the impact point range. This voltage is differentiated and applied to trigger the output blocking oscillator. The time interval between pulses $Д_0$ and $Д_6$ received from the output blocking oscillator corresponds to the required slant-range value to the impact point. The adjustable $Д_4$ delay circuit permits compensation of unit И87 error.

— $V_p$ generating stages consisting of DC amplifiers and electronic switches actuated by the comparator square-wave voltage.

— Selsyn transmitter with a rectifier circuit producing a DC voltage proportional to the sine of the elevation. Summary amplifier ($\sin\epsilon_4$ amplifier) that permits selection of the proper scale coefficient.

— $Д_4$ range multiplier employing a circuit similar to that of range multiplier. It solves equations (6) and (7). The triggering time control of the sawtooth oscillator circuit permits compensation for the error of the target range shaping stages.

— Converter that transforms into a DC voltage the time interval between the blanks designating the beginning of elevation angle registration inside the scan sector and the tracking gate position.

Comments:

1. The commands are reproduced here essentially as received. Their separation is not clearly indicated.

2. This does not follow logically. Substitution of $Д_4$ for $V\cos\gamma_4$ in equation (2) would give

$$Д_6 = \frac{V_p}{Д_4 + V_p \cos\phi}$$

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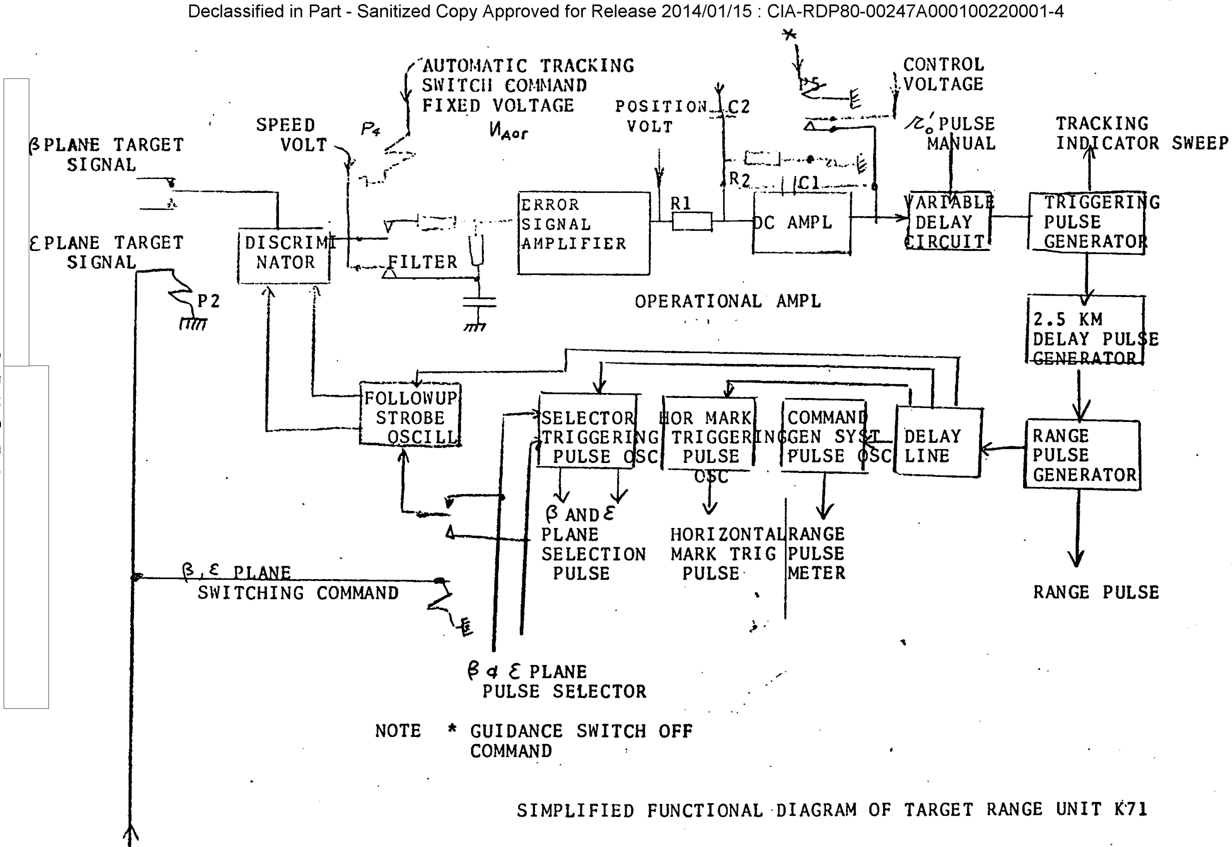


NOTE * GUIDANCE SWITCH OFF COMMAND

SIMPLIFIED FUNCTIONAL DIAGRAM OF TARGET RANGE UNIT K71

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LAYOUT

| | |
|---|---|
| 6A | 6B |

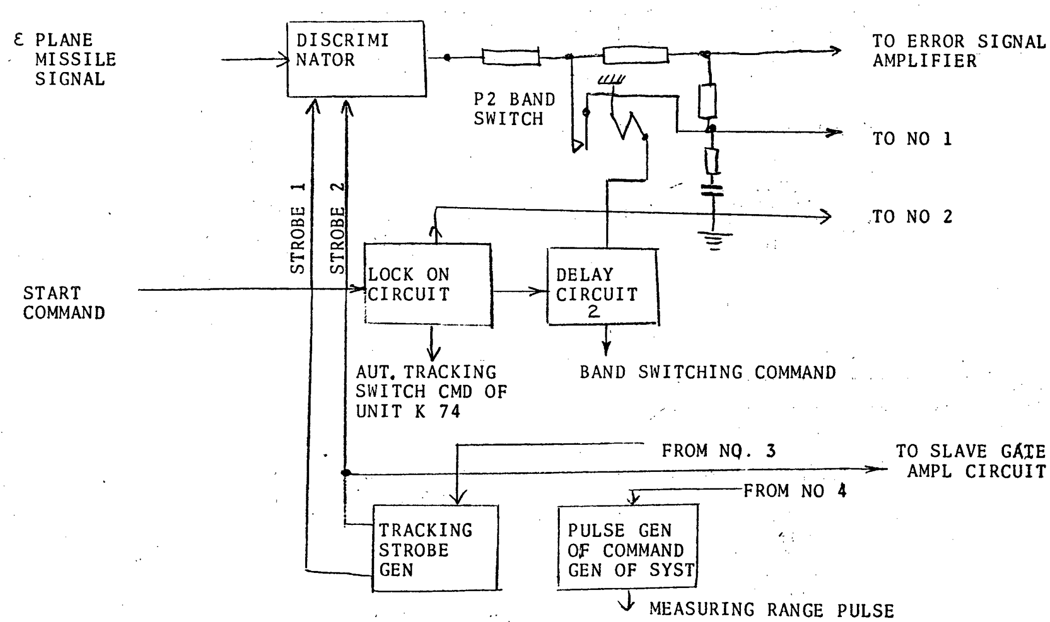
6A

SIMPLIFIED FUNCTIONAL DIAGRAM OF MISSILE RANGE UNIT K 72









6B





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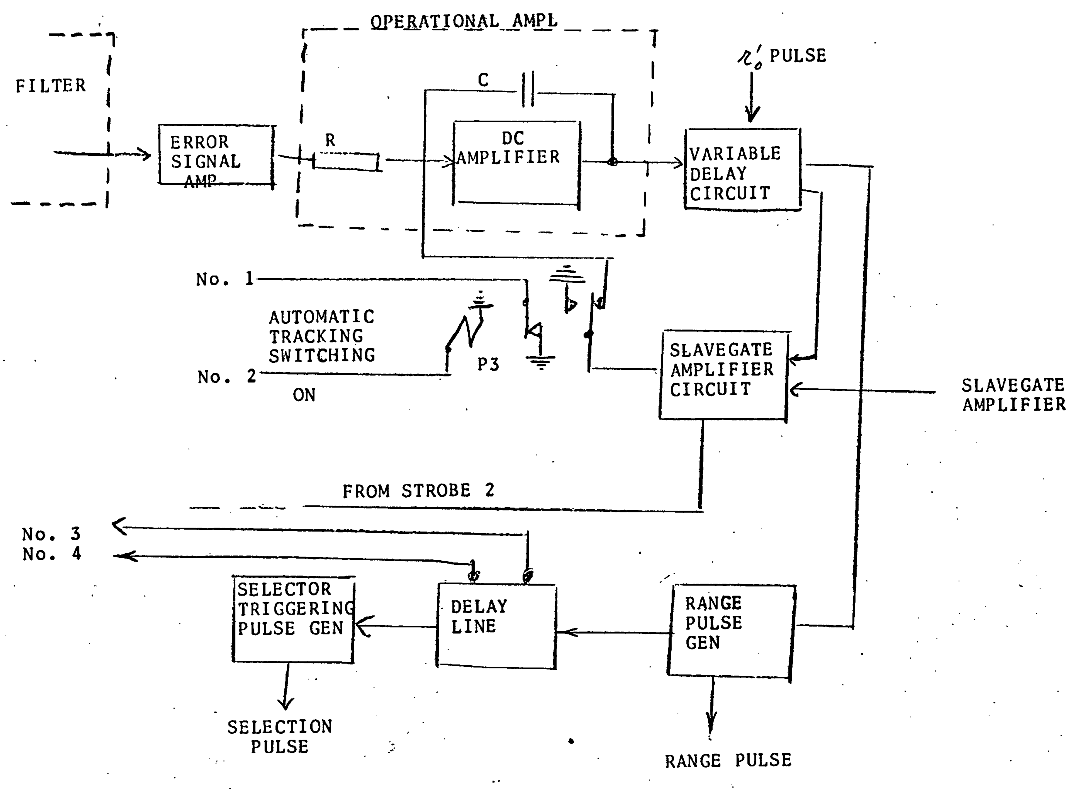


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SIMPLIFIED FUNCTIONAL DIAGRAM OF TARGET ANGULAR UNIT K 73